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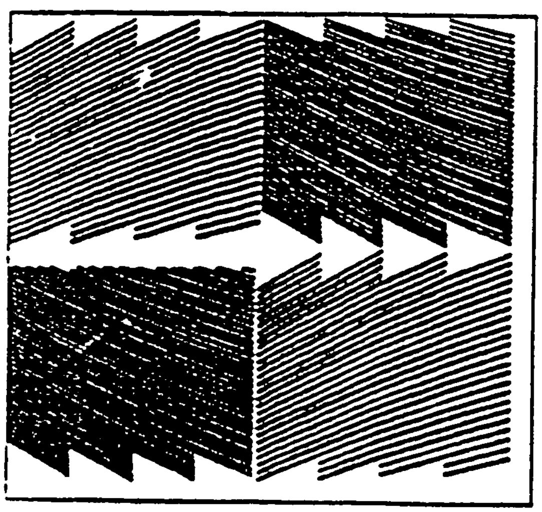

(57) Abstract

A pixellated diffraction grating in which each pixel of the grating is an individual optical diffraction grating and the pixellated diffraction grating when illumitated generates an optically variable image. The pixels are arrayed in a multiplicity of groups of pixels in each of which the pixels are arranged according to a predetermined rule for the pixellated diffraction grating, whereby to produce a visually observable effect in the optically variable image generated when the pixellated diffraction grating is illuminated.

SECURITY DIFFRACTION GRATING WITH SPECIAL OPTICAL EFFECTS

Field of the Invention

This invention relates to diffraction gratings and to their manufacture and in particular provides security diffraction gratings which may be adapted for application as security devices, for example, in currency notes and credit cards.

Background Art

The present applicant's prior international patent publication WO91/03747 (application no. PCT/AU90/00395) discloses a pixellated diffraction grating which, when illuminated, generates a recognisable but optically variable image. The diffraction grating is produced by mapping each pixel of an optically invariable form of the image to a respective pixel of the pixellated diffraction grating. The pixellated diffraction gratings have become known as pixelgrams. According to preferred aspects of the arrangement disclosed in the International application, the respective diffraction grating of each grating pixel comprises a plurality of reflective or transmissive lines having a curvature which is inversely proportional to a chroma or colour value. In the practical application of the technique a master pixellated grating is produced by forming reflective grooves in a metallised surface by electron beam lithography. Such master gratings can then be used to produce a very large number of foils for application as security devices to currency notes, credit cards, travellers cheques and the like.

By virtue of this earlier disclosed invention, it is possible to produce diffraction gratings which generate realistic text and portrait images of near photographic quality. The images may be sharply defined and optically variable under most lighting conditions including very diffuse sources, whereas holograms produce very fuzzy images and lose their optical variability under overcast lighting conditions. The images generated also exhibit a high degree of structural stability with respect to bending undulations of the grating surface, and are therefore suitable

security devices for currency notes, share certificates and the like.

Disclosure of the Invention

It has now been realised that visually observable effects can be produced with pixelgrams which further enhance their utility as security devices. In general terms, this is achieved, in accordance with present invention, by grouping the pixels of the pixellated diffraction grating and arranging the pixels within each group according to a predetermined rule.

The invention accordingly provides, in one aspect, a pixellated diffraction grating in which each pixel of the grating is an individual optical diffraction grating and the pixellated diffraction grating when illuminated generates an optically variable image. The pixels are arrayed in a multiplicity of groups of pixels in each of which the pixels are arranged according to a predetermined rule for the pixellated diffraction grating, whereby to produce a visually observable effect in the optically variable image generated when the pixellated diffraction grating is illuminated.

In another aspect, the invention provides a method of forming a diffraction grating, comprising producing a counterpart pixellated diffraction grating of a substantially optically invariable image wherein each pixel of the optically invariable image is mapped to at least one respective pixel of the pixellated diffraction grating, the arrangement of grating pixels being such that the pixellated diffraction grating when illuminated generates an optically variable reproduction of said optically invariable image, wherein the pixels of the pixellated diffraction grating are arrayed in a multiplicity of groups of pixels in each of which the pixels are arranged according to a predetermined rule for the pixellated diffraction grating, whereby to produce a visually observable effect in said optically variable reproduction of the optically invariable image.

According to one embodiment, each group of pixels comprises two or more similar pixels. Each pixel may be a selected portion of an initially generated larger grating pixel derived, for example from the original optically invariable image. The visually observable effect with this embodiment is a modification eg an enhancement of the relative intensity of the positive or negative components of the images

generated by the pixellated diffraction grating when illuminated.

In a further modification, the individual optical grating comprising at least one pixel in each group may be rotated with respect to the other(s), preferably by inversion through 180°. The visually observable effect in this case is the presence of two sets of images at different viewing angles.

In a further embodiment, the pixels of each group may comprise grating pixels derived from two or more different optically invariable images. By appropriate selection of the parameters of the respective different gratings, two different optically variable images may be generated at different angles of observation. It will be appreciated that such a dual image pixellated diffraction grating can be regarded as a "two-channel" system.

In a still further embodiment, the pixels of each group may comprise different diffraction gratings which are not only relatively rotated but in which the lines are of a different curvature and/or density so that two sets of images of distinct colour and/or shading are present at different viewing angles. These images may be otherwise similar or different.

By "image diffraction pattern" in the context of this specification is meant the optical image observed by the naked eye focused on the grating when it is illuminated by an arbitrarily extended diffuse source of finite width such as a fluorescent tube. The term "diffraction grating" as employed herein indicates a grating of either reflective or transmissive lines. A pattern is described herein as "optically variable" where it varies according to the position of observation and is "structurally stable" if its broad form at any given position of observation is not materially altered by slight distortions of the grating surface.

The pixels are preferably rectangular, most preferably square, of edge length less than 200 micron, most preferably 125 micron or less.

Brief Description of the Drawings

The invention will be further described, by way of example only, with reference to the accompanying drawings, in which:

Figures 1 and 2 are respective photo prints of an original optically invariable

structurally stable black and white image, and of the diffraction image of a corresponding pixellated diffraction grating produced according to the concepts disclosed in International Patent Application No. PCT/AU90/00395;

Figure 3 is a greatly magnified representative pixel from Figure 2;

Figures 4A and 4B are alternative groups of pixels of a pixellated diffraction grating according to embodiments of the present invention;

Figure 5 is a representative pixel group of a two-channel pixellated diffraction grating according to a further embodiment of the present invention; and

Figure 6 is a representative pixel group of a two-colour pixellated diffraction grating according to a still further embodiment of the invention.

Description of the Preferred Embodiment

A brief preliminary explanation will first be given of the principles set out in International Patent publication WO 91/03747 (Application No. PCT/AU90/00395). For the purposes of this explanation, reference is made to the optically invariable structurally stable black and white image of Queen Elizabeth II depicted in Figure 1.

To produce the corresponding pixellated diffraction grating the image of Figure 1 is first divided up into 0.125 mm square pixels and the chroma or colour value, in this case the grey level, of each pixel is assessed in turn. This process is typically carried out by exposing the image to a video camera coupled to a suitable computer system, the grey level for each pixel being stored in the computer memory. Using a predetermined function $S_{ij}(x,y)$, a pixellated grating is produced, for example by electron beam lithography. In this grating, each pixel is an individual optical diffraction grating of the associated pixel in the original image and also a function of the assessed grey level of that associated pixel of the original image. It will be understood that each pixel of the original image is mapped to a respective pixel of the pixellated grating.

The nature of $S_{ij}(x,y)$ is more fully explained in the aforementioned international application.

Figure 2 is the diffraction image at a given viewing angle generated when the pixellated grating is illuminated. This image consists of 166 x 208 pixels, each 0.125

mm square. The actual grating size is 20.75mm x 26mm and there are 14 grey levels in the assessment scale. The pattern is a visually recognisable but optically variable reproduction of the original optically invariable image of Figure 1.

A magnified view of an exemplary pixel grating is shown in Figure 3. This is actually a computer plot of one of the pixel gratings produced from Figure 1 and the optical effect arising from slight discontinuities in the lines is a printer artefact. The lines are shallow parabolas. The effect of decreasing the grey level parameter is to spread the lines apart, more at the centre than at the edges, thereby increasing the curvature of each parabola. This of course has the effect of lightening the grey level of the pixel in the grating image diffraction pattern so that the overall effect is that the grating image diffraction pattern is a pixellated visually recognisable reproduction of the original image. The pixel of Figure 3 is for the lightest of the 14 available shades of grey. It will be seen in Figure 3 that each curved grating line or groove is approximated by four straight line segments at different angles and connected end to end. Each straight line segment is in reality a miniature polygon in the shape of a rhombus with a well defined width.

In general it will be appreciated that $S_{ij}(x,y)$ may be adjusted to select the brightness and stability of each pixel, choose the colour and orientation of each pixel, fix the distance and angle at which the diffracted image has maximum clarity and finally to choose the light sources that give maximum effect to the diffracted portrait image.

It will be understood that the size of pixel chosen determines the degree of pixel resolution in the observed diffraction image. It is found that a 60 micron edge length gives smooth image appearance, but smaller or larger pixel sizes may be appropriate. A lower limit may arise from diffraction effects between pixels. Moreover, groove or line curvature across a pixel determines both local image intensity, eg shading, and local optical structural stability. Groove or line spacing in each pixel determines local colour properties, with non-primary colours generated by a pixel mixing. Average groove or line orientation determines movement and colour effects, and the number of distinct values of average curvature and average spacing may be viewed as defining the pixelgram palette, by analogy with the language of computer graphics.

As mentioned, a pixellated diffraction grating of the form of Figure 2 may be constructed by programming an electron beam lithography system. This process is further detailed in the aforementioned International patent application.

In accordance with the present invention, the basic system just described may be further modified by grouping the pixels in a grating in small groups of pixels in each of which the pixels are arranged according to a predetermined rule. According to one embodiment, each group of pixels may be of dimensions similar to the pixels of the grating shown in Figure 2 but contain smaller component pixels according to the selected rule. In turn, these component pixels may comprise segments of a larger pixel such as that of Figure 3 which would otherwise be produced by the basic method. Figure 4A depicts a group of two pixels which are each similar and comprise the left half segment of an initial grating similar to Figure 3. Because it has been realised that in a grating such as that shown in Figure 3, the closer spaced lines towards the left and towards the top control the positive order components of the images generated when the grating is illuminated and the greater spaced region towards the right and towards the bottom more controls the negative order components, a pixellated diffraction grating comprising pixel groups of the kind shown in Figure 4A tends to exhibit a more even matching of the negative and positive components of the image.

In contrast, a grating constructed from groups of pixels such as that shown in Figure 4B causes a strong positive bias to the image so that the positive components of the image are enhanced. The arrangement of Figure 4B is produced by taking the top left hand quadrant of an initial grating pixel similar to that of Figure 3 and then repeating this segment in the four corners of a pixel group of similar external square dimensions to the original pixel. A pixellated diffraction grating containing groups similar to that of Figure 4B creates a second visual effect by adopting a further rule that the right hand segment pixels are inverted through 180° relative to the left hand segments. The result is that two separate series of positive enhanced images are viewed at different rotational positions of the grating about an axis normal to the grating.

Figure 5 depicts a further level of sophistication in accordance with the present invention. Here, each group of grating pixels is arranged, as before, within

a square and contains four grating pixels in its respective quadrants. Diagonally opposite quadrants contain pixels derived from a first optically invariable image, while the other pair of diagonally opposite quadrants contain pixels derived from a second optically invariable image. These initial derivations are in accordance with the invention of the aforementioned International patent application. By again setting different orientations for the lines of the respective pairs of grating pixels (in this case, inverted by 180°), the two different images will be observed at different relative angles of view. A pixellated diffraction grating containing grouped pixels according to Figure 5 may therefore be viewed as a "two-channel" grating.

By way of example, the two images may be different views of the same person (eg looking in different directions) or two completely different images eg of a recognisable person on the one hand and a corporate logo on the other.

Figure 5 is for a two-channel pixelgram. It is thought possible that a three-channel pixelgram would still result in good resolution of the images, but that four channels would result in some degree of overlap of images, or, to reduce overlap, would necessitate a pixel group dimension which would adversely affect resolution of the individual images. One example of a three-channel group which may have significant practical utility would use three pixels within each group respectively derived from a portrait of maximum colour variation, a corporate logo and a separate pattern, the latter two being each formed in three colours only which were selected so as to have diffraction angles which did not overlap.

It was earlier mentioned that groove or line spacing in each pixel determines local colour properties, while groove or line curvature across a pixel determines local image intensity, eg shading. Thus, in the two-channel pixelgram just described, the two different images may have different line curvature and/or densities so that the images are of distinct colours and/or shading/intensity. In a simpler embodiment, the images may be similar but of distinct colour and/or shading intensity. A group of pixels in accordance with such a rule is depicted in Figure 6: the respective otherwise similar images will be a yellow and a green at the optimum viewing angles, and the distinct orientations of the pixels will, as before, ensure that the differently coloured images will be viewed at quite distinct angles and will substantially not overlap.

CLAIMS:

1. A pixellated diffraction grating in which each pixel of the grating is an individual optical diffraction grating and the pixellated diffraction grating when illuminated generates an optically variable image, wherein the pixels are arrayed in a multiplicity of groups of pixels in each of which the pixels are arranged according to a predetermined rule for the pixellated diffraction grating, whereby to produce a visually observable effect in the optically variable image generated when the pixellated diffraction grating is illuminated.

2. A pixellated diffraction grating according to claim 1 wherein each group of pixels comprises two or more similar pixels.

3. A pixellated diffraction grating according to claim 2 wherein each pixel is a selected portion of an initially generated larger grating pixel derived from the original optically invariable image, whereby said visually observable effect is a modification of the relative intensity of the positive or negative components of the images generated by the pixellated diffraction grating when illuminated.

4. A pixellated diffraction grating according to claim 1, 2 or 3 wherein the individual optical diffraction grating comprising at least one pixel in each group is rotated with respect to the other(s), whereby said visually observable effect is the presence of respective sets of images at different viewing angles.

5. A pixellated diffraction grating according to claim 4 wherein said rotation comprises inversion through 180°.

6. A pixellated diffraction grating according to claim 4 or 5 wherein respective pixels of each group have different grating line curvature and/or density whereby said visually observable effect is the presence of respective images of distinct colour and/or shading at different viewing angles.

7. A pixellated diffraction grating according to any preceding claim wherein the pixels of each group comprise different diffraction gratings derived from two or more different optically invariable images, and wherein the parameters of the respective different diffraction gratings are selected so that two different optically variable images are generated at different angles of observation.

8. A method of forming a diffraction grating, comprising producing a counterpart pixellated diffraction grating of a substantially optically invariable image, in which each pixel of the optically invariable image is mapped to at least one respective pixel of the pixellated diffraction grating, the arrangement of grating pixels being such that the pixellated diffraction grating when illuminated generates an optically variable reproduction of said optically invariable image, wherein the pixels of the pixellated diffraction grating are arrayed in a multiplicity of groups of pixels in each of which the pixels are arranged according to a predetermined rule for the pixellated diffraction grating, whereby to produce a visually observable effect in said optically variable reproduction of the optically invariable image.

9. A method according to claim 8 wherein each group of pixels comprises two or more similar pixels.

10. A method according to claim 9 wherein each pixel is a selected portion of an initially generated larger grating pixel derived from the original optically invariable image, whereby said visually observable effect is a modification of the relative intensity of the positive or negative components of the images generated by the pixellated diffraction grating when illuminated.

11. A method according to claim 8, 9 or 10 wherein the individual optical diffraction grating comprising at least one pixel in each group is rotated with respect to the other(s), whereby said visually observable effect is the presence of respective sets of images at different viewing angles.

12. A method according to claim 11 wherein said rotation comprises inversion

through 180°.

13. A method according to claim 11 or 12 wherein respective pixels of each group have different grating line curvature and/or density whereby said visually observable effect is the presence of respective images of distinct colour and/or shading at different viewing angles.

14. A method according to any one of claims 8 to 13 wherein the pixels of each group comprise different diffraction gratings derived from two or more different optically invariable images, and wherein the parameters of the respective different diffraction gratings are selected so that two different optically variable images are generated at different angles of observation.

FIGURE 1

FIGURE 2

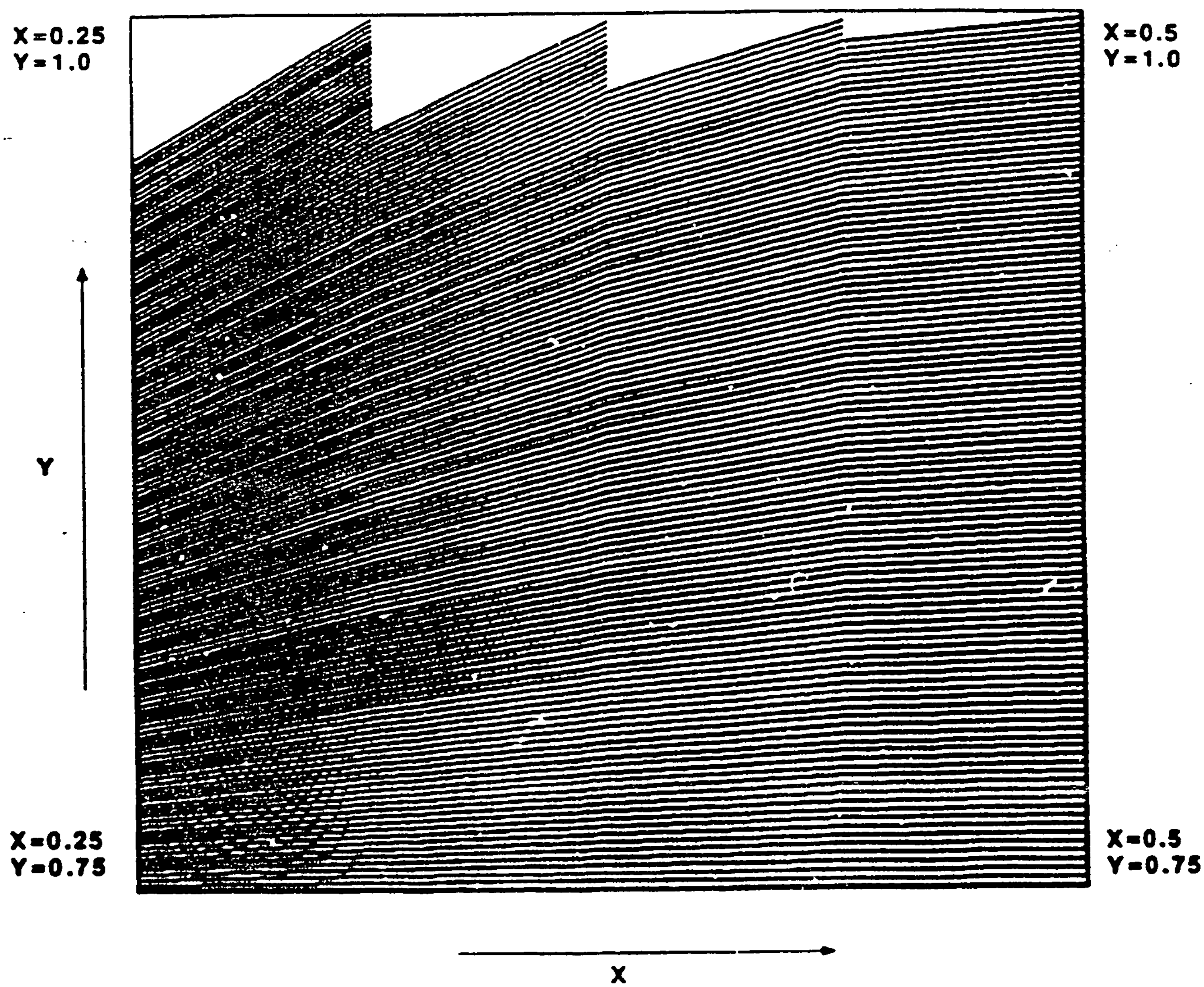

FIGURE 3

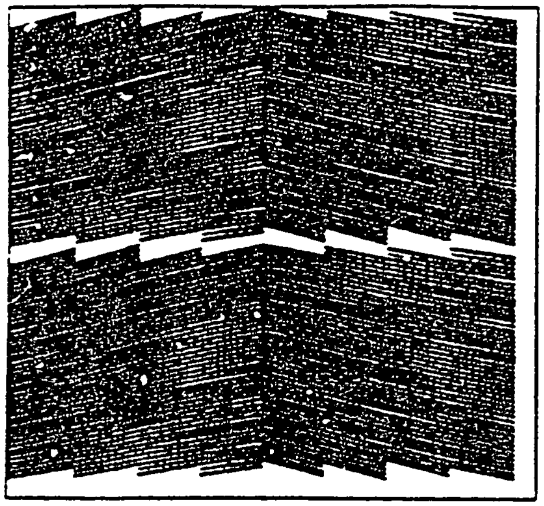

FIGURE 4A

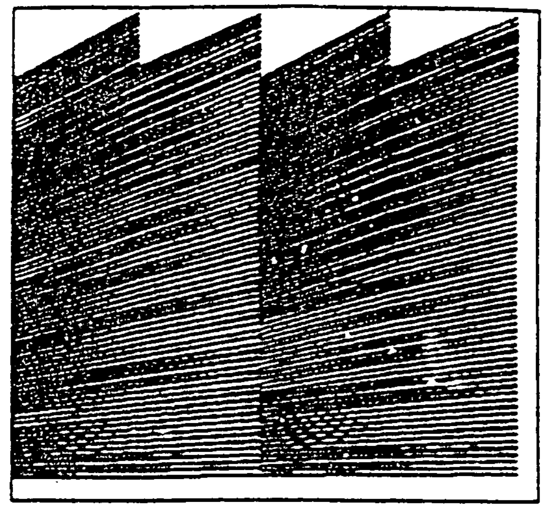

FIGURE 4B

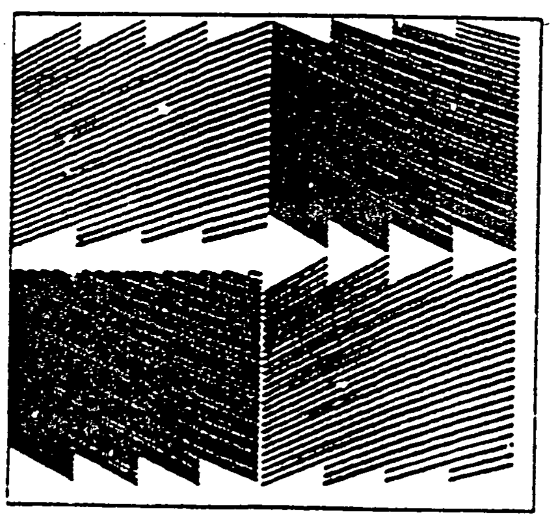

FIGURE 5

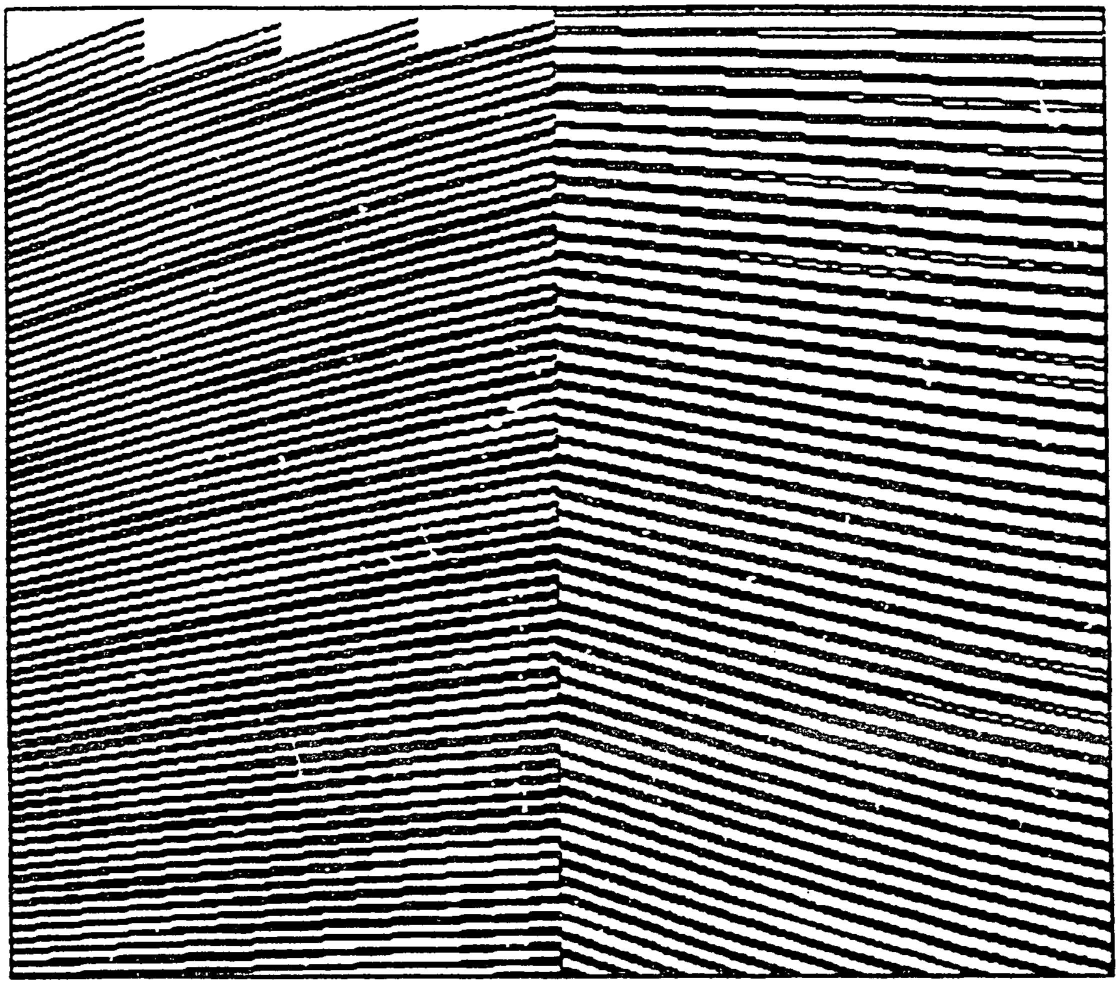

Figure 6

A. CLASSIFICATION OF SUBJECT MATTER
Int. Cl.[5] G02B 5/18, 27/44, B44F 1/12, B42D 15/10, 209:00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC : G02B 5/18, 27/44, B44F 1/12, B42D 15/10, 209:00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
AU : IPC as above

Electronic data base consulted during the international search (name of data base, and where practicable, search terms used)
DERWENT : pixel and diffraction grating
JAPIO : pixel and diffraction grating

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to Claim No.
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P,X	AU,A, 10499/92 (TOPPAN PRINTING CO. LTD) 13 August 1992 (13.08.92) whole document	1-3,7-10
	AU,B, 53729/90 (635255) (LANDIS & GYR BETRIEBS AG) 24 October 1991 (24.10.91) (& US,A, 5032003 & EP,A1, 0375833)	
X	whole document	1,2,4-9,11-14
Y	whole document	3,10

[x] Further documents are listed in the continuation of Box C.

[x] See patent family annex.

* Special categories of cited documents :

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
3 June 1993 (03.06.93)	22 JUNE 1993 (22.06.93)

Name and mailing address of the ISA/AU	Authorized officer
AUSTRALIAN PATENT OFFICE PO BOX 200 WODEN ACT 2606 AUSTRALIA Facsimile No. 06 2853929	M.E. DIXON Telephone No. (06) 2832194

C(Continuation).	DOCUMENTS CONSIDERED TO BE RELEVANT	
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A	whole document	
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X	page 13, lines 13-17; page 13, line 21 - page 14, line 3; page 17, line 13 - page 18, line 15; Fig 6	1,2,4-6
	EP,A2, 0467601 (APPLIED HOLOGRAPHICS CORPORATION) 22 January 1992 (22.01.92)	
X	column 3, line 11 - column 4, line 36; Fig 1,2	1-7
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X	abstract	1,2
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A	Proceedings of SPIE - The International Society for Optical Engineering, Volume 526, published 1985 by SPIE, Bellingham, WA, USA, Stein J.A. et al, "A Display Based on Switchable Zero Order Diffraction Grating Light Valves", see Abstract, Introduction & Fig. 1,2,3	

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/AU93/00102

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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